Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results

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Grant Number: N000141010508

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LONG-TERM GOALS

The goal of this research is to develop greater understanding of the how the flocculation of fine-grained sediment responds to turbulent stresses and how this packaging of sediment affects optical and

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE **Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University Of Maine,School of Marine Sciences,5706 Aubert Hall,Orono,ME,04469-5706**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

acoustical properties in the water column. Achieving these goals will improve the skill of sediment transport models and hence prediction of underwater visibility.

OBJECTIVES

1. Quantify the effects of aggregation dynamics on the size distribution of particles in the bottom boundary layer;
2. Quantify how changes in particle packaging affect the optical and acoustical properties of the water column.
3. Develop models describing the associations between particle aggregation, stress, and the acoustical and optical fields.

APPROACH

The approach is to obtain measurements that permit comparisons of temporal evolution of bottom stress, suspended particle size, and optical and acoustical properties in the bottom boundary layer. We measure optical and acoustical properties of the water column by coupling an ac-9 (9 wavelength absorption and attenuation) and a two backscattering + CDOM fluorometer to the USGS tripod on their profiling arm (hence resolving the first 2m of the bottom boundary layer). Coupling the ac-9 with a switch and a filter, we are able to obtain calibration independent optical properties of particles (Slade et al., 2010) which provide us concentration, size and compositional information regarding the particles. In addition, it allows us to obtain the parameters needed to compute underwater visibility and provide the inputs necessary to Dr. N. Farr's group to model the optical field affecting underwater optical communication.

Collaborating with Dr. Hill, Sherwood and Trowbridge, our data will be used to develop and constrain a sediment concentration module that will be incorporated to the Community Sediment Transport Modeling System (CSTMS).

WORK COMPLETED

Work in 2010-2011 focused on two areas. First, we worked on publication of results from past field experiments. Second, we prepared for another field season in September and October of 2011 at the Martha's Vineyard Coastal Observatory where we integrated our instrument into the USGS tripod which resolves the bottom 2m of the bottom boundary layer. To date we have collected nearly continuous two and a half weeks of optical data.

RESULTS

With our past OASIS support we have gathered three one-month-long time series of observations linking physical forcing, sediment concentration and size distribution, and optical properties. We are collecting a fourth data set in September and October 2011. Over a range of environmental conditions, the conversion from SPM to optical properties is more predictable than the theory that assumes constant-density particles suggests. The broad conclusion that can be drawn from our work is that particle and optical properties are easier to predict when the stress on the seabed is adequate to resuspend particles. When stresses are too low to resuspend sediment, biology and chemistry determine the concentration, composition, and size of particles in suspension, so biology and chemistry also determine optical properties. When stress grows large enough to resuspend particles, however, particle and optical properties are more closely linked to physical forcing, which is fundamentally more predictable. As well, the composition of particles becomes more uniform with increasing stress.

We have used data from OASIS 2007 to examine the lack of sensitivity of particulate beam attenuation to particle size. Estimated *SPM* and measured c_p from the LISST were linearly correlated throughout the experiment, despite wide variations in particle size. The slope of the line, which is the ratio of c_p to *SPM*, was 0.22. Individual estimates of c_p:*SPM* were between 0.2 and 0.4 for volumetric median particle diameters ranging from 10 to 150 μm (Figure 1). The wide range of values in c_p:*SPM* found in the literature, which has usually been blamed on variable particle size, instead likely results from three factors capable of producing factor-of-two variability in the ratio: particle size, particle composition, and differences among acceptance angles of commercial beam-transmissometers. This work has been published in *JGR Oceans* (Hill et al., 2011).

Our field and laboratory experiments contributed to further our understanding of the effect of aggregation on optical properties; manipulating aggregates in the environments, we observed their effect on attenuation and forward scattering. We developed a new aggregate density parameter, the ratio of the beam-attenuation to total particle volume; this factor is low for suspensions of highly flocculated particles and large for dense particles (Fig. 2). We found that while the particulate beam attenuation spectra changes during aggregation similar changes are not seen in the backscattering spectrum. This is important because spectral backscattering has been proposed as a method to obtain information on particulate size from AUVs. This work has been published in *Optics Express* (Slade et al., 2011).

One of the technical developments we needed to overcome for OASIS was to collect high quality spectral absorption and attenuation of particle over a month long deployment. This is not trivial due to the slow drift and potential fowling of current available technology. Boss's lab developed a system to do it by using an underwater switch that periodically pumped water through a 0.2μm filter and computing the spectral particulate absorption and attenuation as a difference between the measurements without a filter from those with a filter. This work has been published in *JTECH* (Slade et al., 2010).

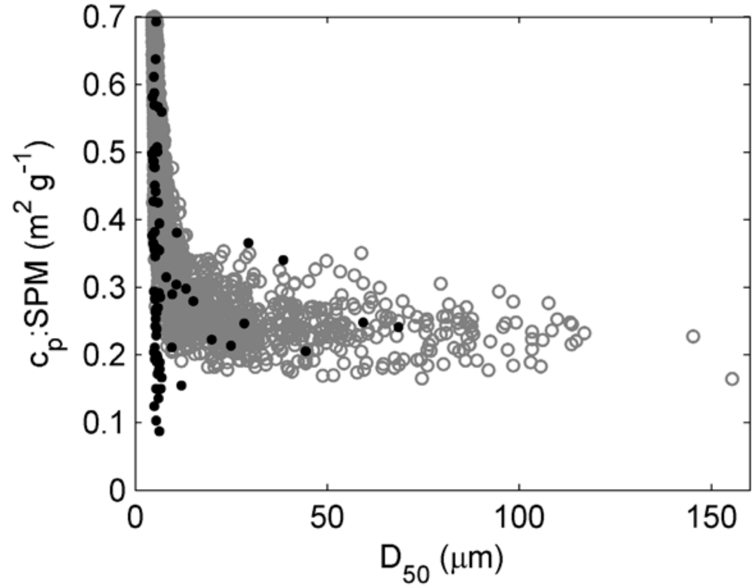

***Figure 1.** The ratio c_p:SPM plotted versus median particle size. Closed black circles are associated with values of SPM measured with the in-situ filtration system. Open gray circles are values associated with SPM estimated every 5 minutes from the merged size spectra and the size-settling velocity data. When median particle size is small, c_p:SPM is variable, but when median particle size grows larger than 10 μm, the value of c_p:SPM is constrained between 0.2 and 0.4. From Hill et al., 2011.*

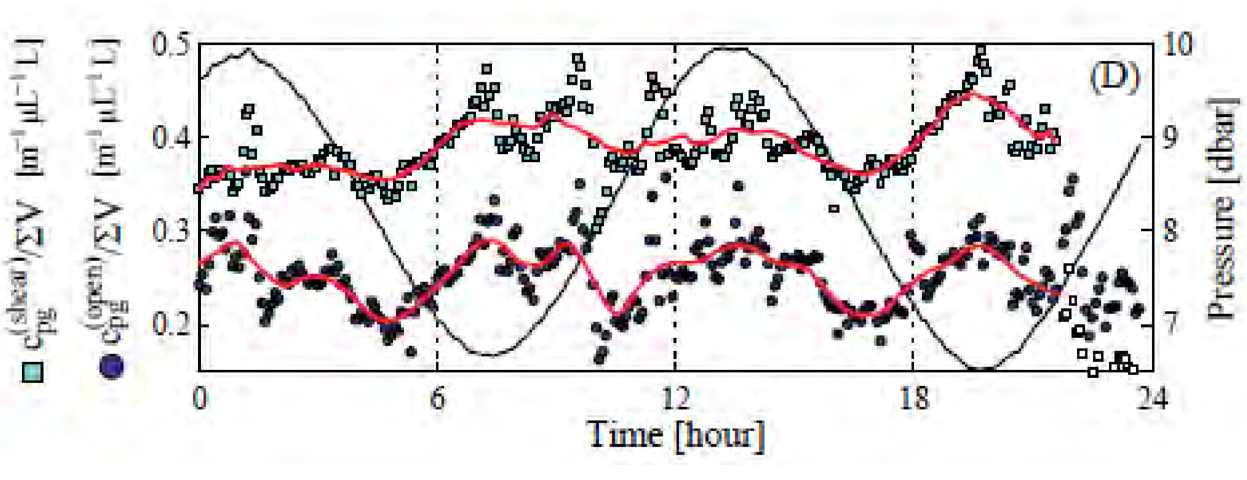

***Figure 2.** Time series of optical and particle size properties during the in situ disaggregation experiment. The experimental package was deployed in a bottom-mounted configuration thus tidal variability is shown as pressure in each plot. Unfilled symbols indicate the control data where the pump and sample chamber were removed from LISST B and both instruments were open to the environment. The ratio of beam-attenuation to volume concentration as measured by the LISST, indicative of aggregates (From Slade et al., 2011).*

IMPACT/APPLICATIONS

The high-resolution time series of particle, optical, and acoustical properties will enhance understanding of the rates and mechanisms by which the water column clears following storm events. This is important for visibility models as well as those for sediment transport.

RELATED PROJECTS

A graduate student (Clementina Russo) is funded to study the link between acoustical and optical properties during OASIS (N000140910577 to E. Boss).

Instruments used in this work have been purchased through a DURIP grant (N000141010776 to E. Boss)

PUBLICATIONS

Hill, P. S., E. Boss, J. P. Newgard, B. A. Law, and T. G. Milligan, 2011. Observations of the sensitivity of beam attenuation to particle size in a coastal bottom boundary layer, J. Geophys. Res., 116, C02023, doi:10.1029/2010JC006539, [published, refereed].

Slade, W. H., E. Boss, G. Dall'Olmo, M. R. Langner, J. Loftin, M. J. Behrenfeld, C. Roesler and T. K. Westberry, 2010. Underway and moored methods for improving accuracy in measurement of spectral particulate absorption and attenuation. *J. Atmos. Ocean. Tech.* 27, 1733-1746. [published, refereed].

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